MAJOR OIL AND GAS PRODUCTION IN OHIO

SENIOR THESIS

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THE OHIO STATE UNIVERSITY

Department of Geology and Minerology

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ABSTRACT

The major oil and gas production in eastern Ohio is from the Berea sands and the "Clinton sands." In the Berea the controlling factors of accumulation of oil and gas are porosity and permeability trends, and not structure. In the "Clinton" the reservoir-controlling parameters are interstitial clay content, shale stringers and laminations, degree of cementing, grain size, pore geometry and thickness. Best production is from thick, more clay- and shale-free distributary-channel deposits and delta platform tidal channels. In northwestern Ohio, the major producing unit is the Trenton limestone. In the Trenton, accumulation is controlled by magnesium-carbonate content and structure. Best production is from true dolomite in structural traps on the northwest limb of the Findlay Arch. In north-central Ohio, the major oil production is from the Copper Ridge Dolomite. Here production is from the E and F members of the Copper Ridge Dolomite, present in erosional remnants on the Knox unconformity.

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ACKNOWLEDGMENT

I am grateful to Dr. Robert L. Bates for his advice, criticism and time in preparing this paper.

Major Oil and Gas Production
In Ohio

Introduction

Bedrock formations of Ohio include limestone, dolomite, shale and sandstone of Paleozoic age. The major structural feature is the Findlay Arch, trending north-northeast in western Ohio, plunging northward at approximately 10 feet per mile (Figure 1). Away from the broad undulating crest of the Findlay Arch, the strata on the northwest limb dip toward the Michigan basin and the strata on the southeast limb dip approximately 40 feet per mile into the Appalachian basin (Carman and Stout, 1934). The youngest exposed bedrock, of Permian age, lies in southeastern Ohio, and the oldest, of Ordovician age, lies in the vicinity of Cincinnati.

Oil and gas have been produced commercially in Ohio since 1860. As shown on Figure 2, productive areas are concentrated on the Findlay Arch in northwestern Ohio, and in the eastern part of the state, where accumulations are related to those of Pennsylvania and West Virginia. There is also a small group of oil fields in Morrow County, north-central Ohio.

Strata from which oil and gas are produced in Ohio (Figure 3) are as follows: in the eastern part of the state, in descending order, First Cow Run, Big Injun, First and Second Berea, Oriskany, Newburg and "Clinton." All the accumulations are basically

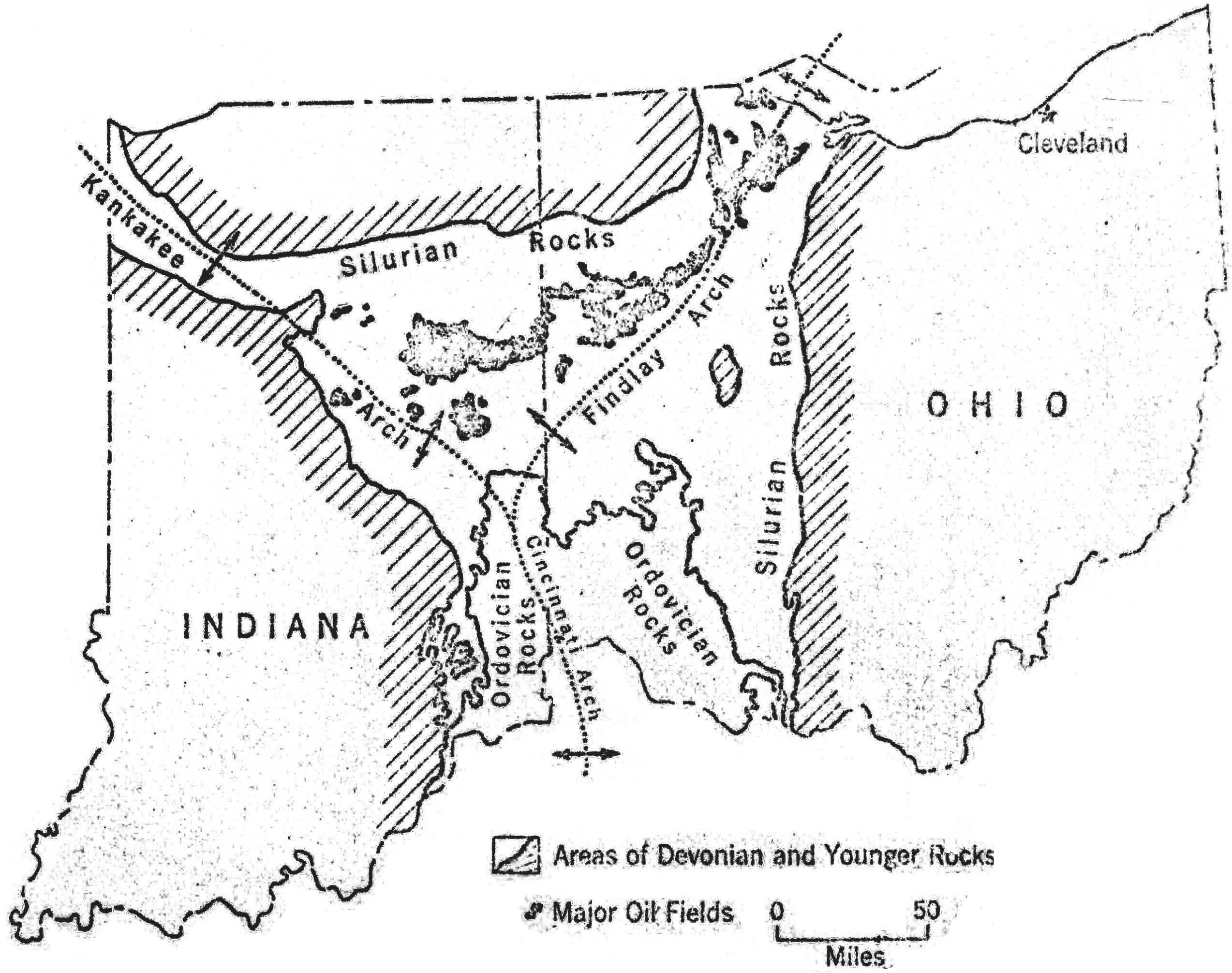


Figure 1. Lima-Indiana district, Indiana and Ohio, showing location of major oil fields in respect to regional structure and areal geology (Landes, 1970).

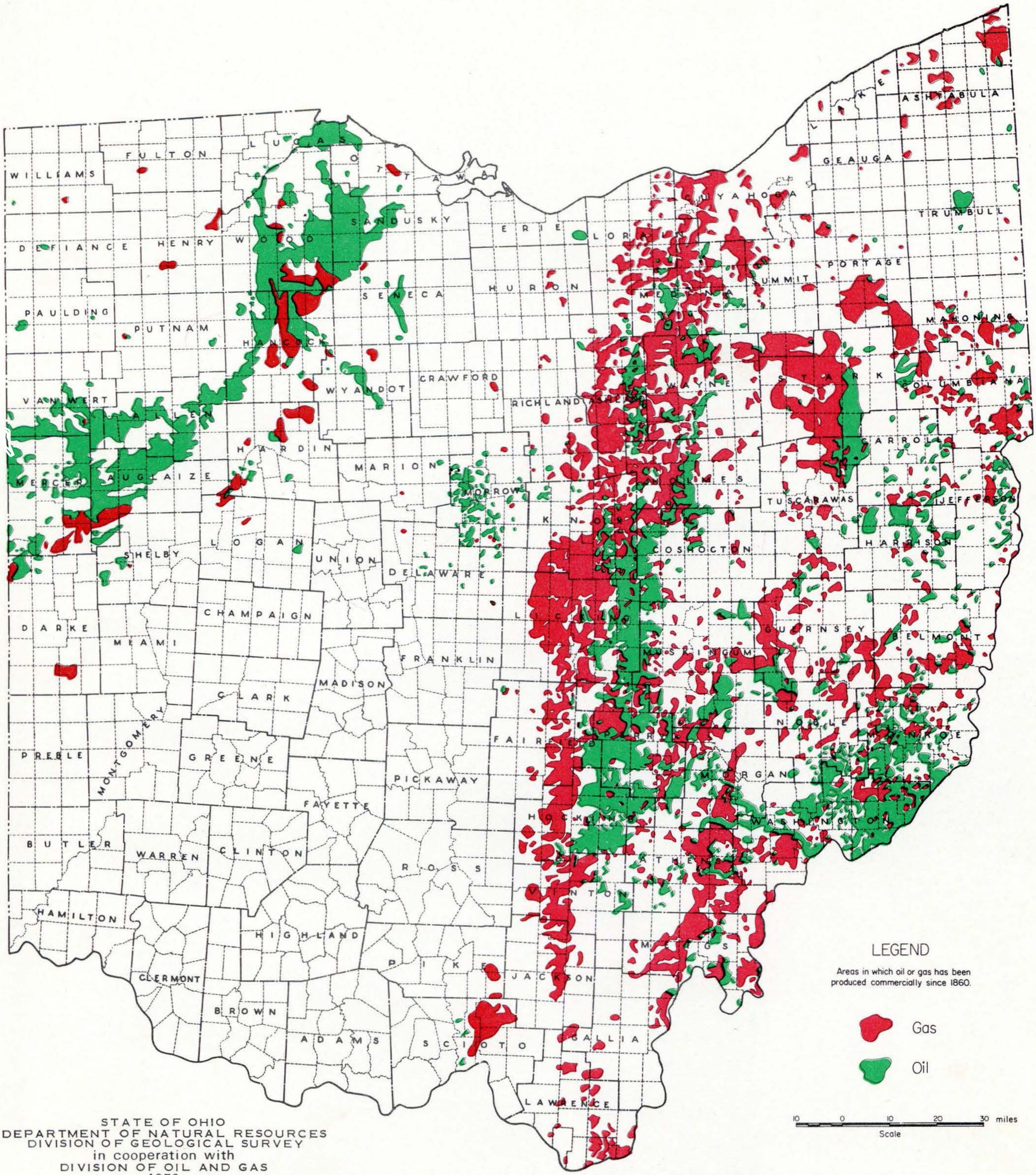


Figure 2. **OIL AND GAS FIELDS MAP OF OHIO**

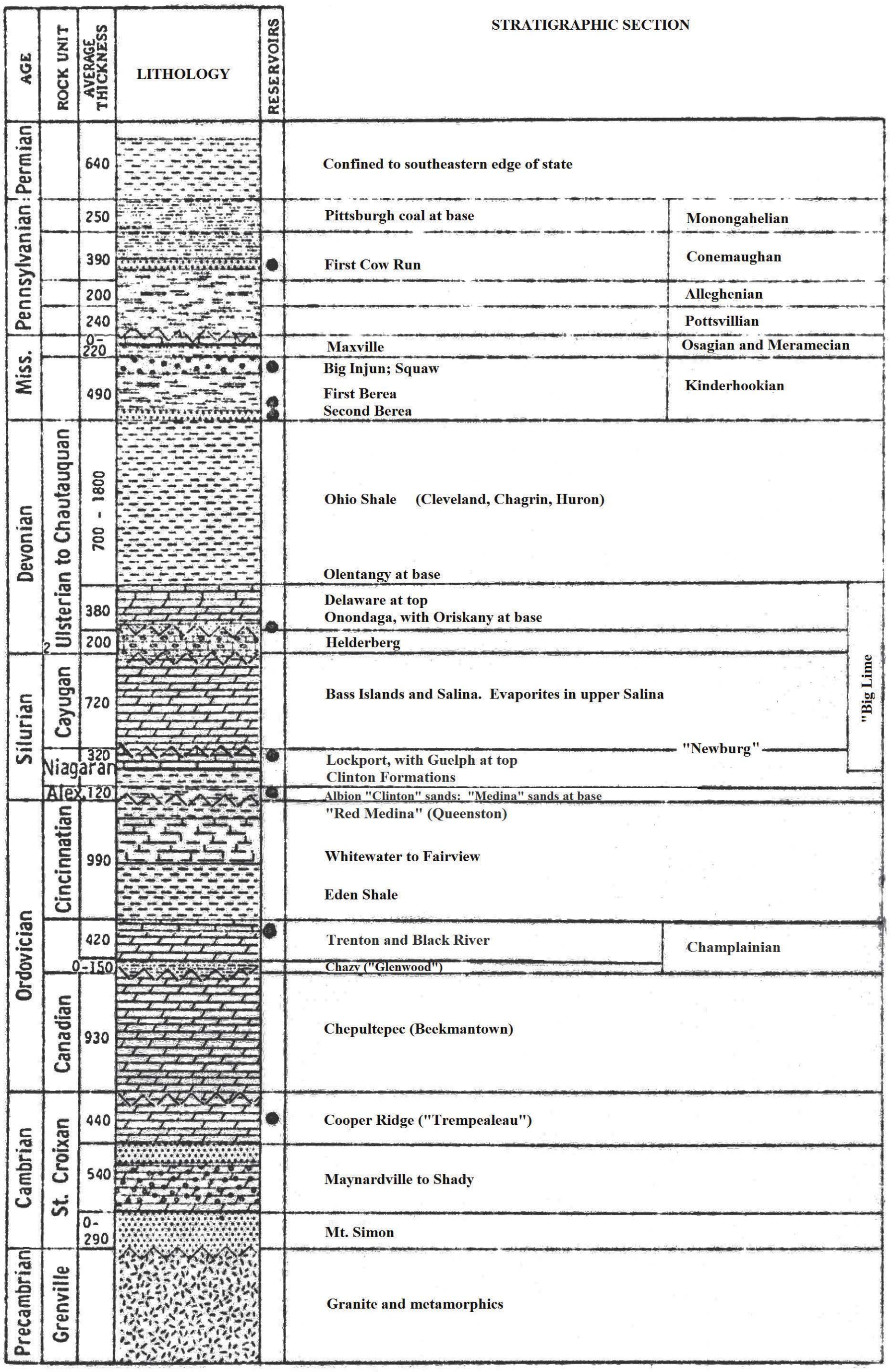


Figure 3. Stratigraphic column in Ohio, showing oil and gas reservoirs (Calvert, 1960).

related to updip stratigraphic pinch-out traps. In northwestern Ohio, the Trenton limestone is productive in the Lima-Indiana field, where accumulation is related to dolomitization on the Findlay Arch. The stratigraphically oldest pools are those from the Copper Ridge Dolomite in Morrow County, where accumulation is related to the Knox unconformity.

Berea Sandstone and "Clinton Sands"

Stratigraphy and Correlation

The youngest major producing unit encountered by the driller in eastern Ohio is the Berea sands. Current producing pools are shown on Plate 1. The Berea, of Early Mississippian age, is persistent in the subsurface throughout central and eastern Ohio and crops out in the vicinity of the type locality at Berea (Newberry, 1870). The Berea locally may be a pebbly and coarse-grained sandstone to a medium-grained siltstone (Rittenhouse, 1946). Correlation of the Berea sandstone with beds in Pennsylvania, West Virginia, and Kentucky is shown in Figure 4. The Bedford shale and Berea sandstone, a wedge of sediments between the Sunbury shale above and the Ohio shale below, represent a cycle of deposition during an oscillation of the land, in eastern Canada and the Appalachin region, and the sea, the Ohio Bay of Bedford and Berea time (Pepper, DeWitt and Demarest, 1954). Pepper concluded, on examination of mineral constituents, sedimentary structures, grain

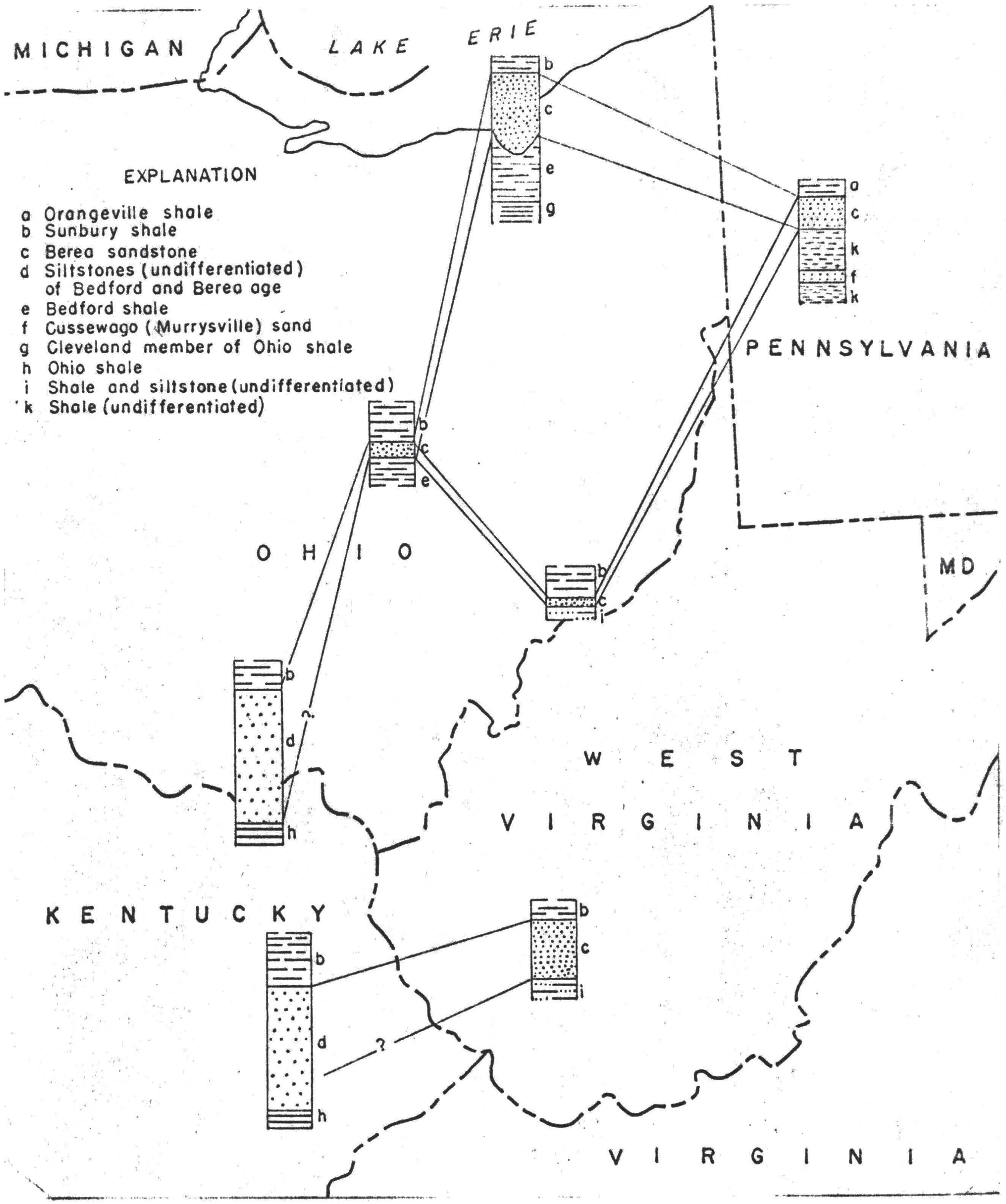


Figure 4. **Representative sections of the lower Mississippian and Upper Devonian rocks in eastern Ohio and adjacent states. The lines limit the sand and silt unit of which the thickness has been mapped in the study of the Bedford shale and Berea sandstone (Pepper, De Witt and Demarest, 1954).**

size, sand thickness, and other data that the sediments of the Bedford and Berea formations were derived from two or three widely separated source areas. Sediments from these areas coalesced to form the Bedford and Berea sediment wedge (Figure 5). One source was eastern Canada, from which sediment was deposited as a great delta fan. The second was in West Virginia and Virginia, from which sediment was carried into the Appalachian basin by two or more river channels. A probable third source was the North Carolina region.

The next older of the major units encountered by the drillers is the "Clinton sands." Current producing pools are shown on Plate 2. The "Clinton sands" of Early Silurian age, are fine-grained, light-gray to red subgraywacke to protoquartzitic sandstone and siltstone, with shale partings, crossbedding, ripple marks, lineations, burrows, load casts, clay galls and other minor sedimentary structures (Overbey and Henniger, 1971).

Early workers correlated these sandstones with the Clinton Group of western New York, but later studies have proved that these sandstones of Ohio are equivalent ot the older Albion Group or Tuscarora Sandstone of Pennsylvania and West Virginia (Rittenhouse, 1949). The name "Clinton sands" is still used by drillers, but is put in quotation marks in geological reports. Correlation with the rock sequence in the vicinity of Niagara Falls, New York, is shown in Figure 6.

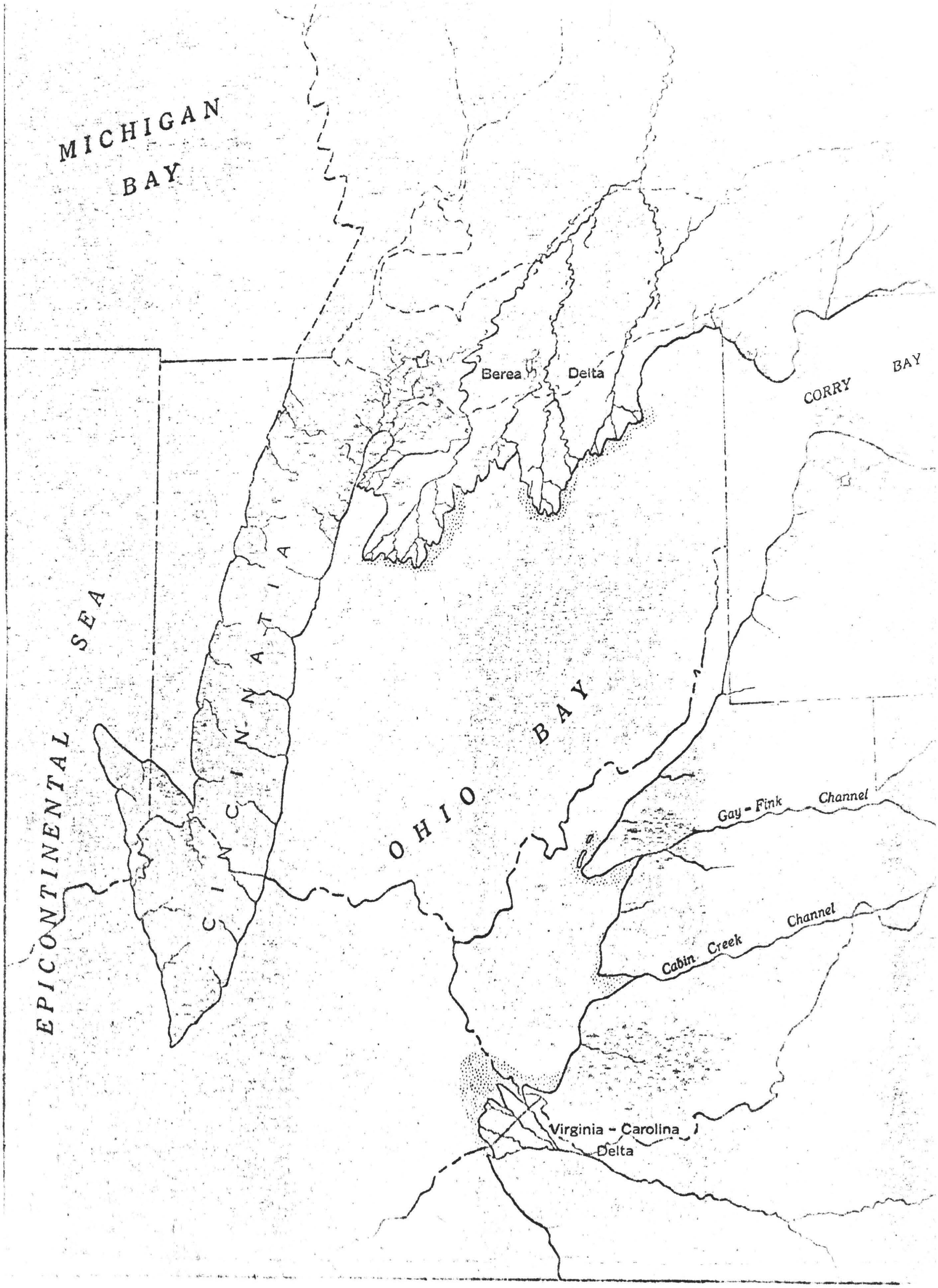


Figure 5. **Paleogeographic map of middle Berea time (Pepper, De Witt, and Demarest, 1954). The Bedford had already been deposited in the Ohio Bay.**

	Mapped area [1]	Niagara Falls area, New York [2]	Remarks
Silurian	Basal Big lime.	Lockport dolomite.	
	Shale, gray to greenish-gray.	Rochester shale.	
	Packer shell.	Irondequoit limestone. Reynales limestone.	Probable equivalents of the Dayton limestone in western Ohio.
	Shale, gray, greenish-gray, and red.	Neahga shale.	Approximate equivalents.
	Sand, stray Clinton.	Thorold sandstone.	
	Sand, red Clinton.	Grimsby sandstone.	
	Sand, white Clinton or Clinton.	Cabot Head shale.	The white Clinton sand of Ohio has no equivalent sand in western New York. It is equivalent to some of the upper part of the Tuscarora sandstone of Pennsylvania.
	Shale and shells.	Manitoulin shale.	
	Shale, gray.	Whirlpool sandstone.	
Ordovician	Shale, red Medina.	Queenston shale.	

[1] Rock units as recorded by drillers.
[2] Gillette, 1940, 1947.

Figure 6. Correlation of the rock sequences of "Clinton sands" in eastern Ohio with the rocks exposed in the vicinity of Niagara Falls, New York (Pepper, De Witt and Everhart, 1953).

The "Clinton sands" lie 150 to 200 feet below the Lockport Dolomite (basal "Big Lime"). Beneath the "Clinton" is gray shale, 50 to 80 feet thick, which lies on the Queenston shale or "Red Medina." At least two thin carbonate units overlie the "Clinton" sandstone, separated from it and from each other by thin shale beds. The "Clinton sands" are divided into three units, which belong to a deltaic complex reflecting terrestrial-transitional and littoral-neritic subenvironments. These are, in descending order, the "Second Clinton" sandstone (drillers' "White Clinton"), a delta platform-barrier bar-beach complex, which includes tidal channel deposits; the "First Clinton" sandstone (drillers' "Red Clinton") a subaerial delta complex including sediments of estuary, tidal flat, tidal creek, beach ridge, river-mouth bar, and other subenvironments, deposited on the "Second Clinton" during regression; and the "Stray Clinton", a transgressive deposit showing some reworking of the "First Clinton" sandstone (Overbey and Henniger, 1971). See Figures 7 and 8.

Accumulation

Area N, Figure 9, consists of shoreline and near-shoreline deposits of sand and silt. This area is cut by sand-filled channels which were filled by middle Berea time, and then a thin layer of sand was deposited over the interstream area (Pepper, De Witt and Demarest, 1954).

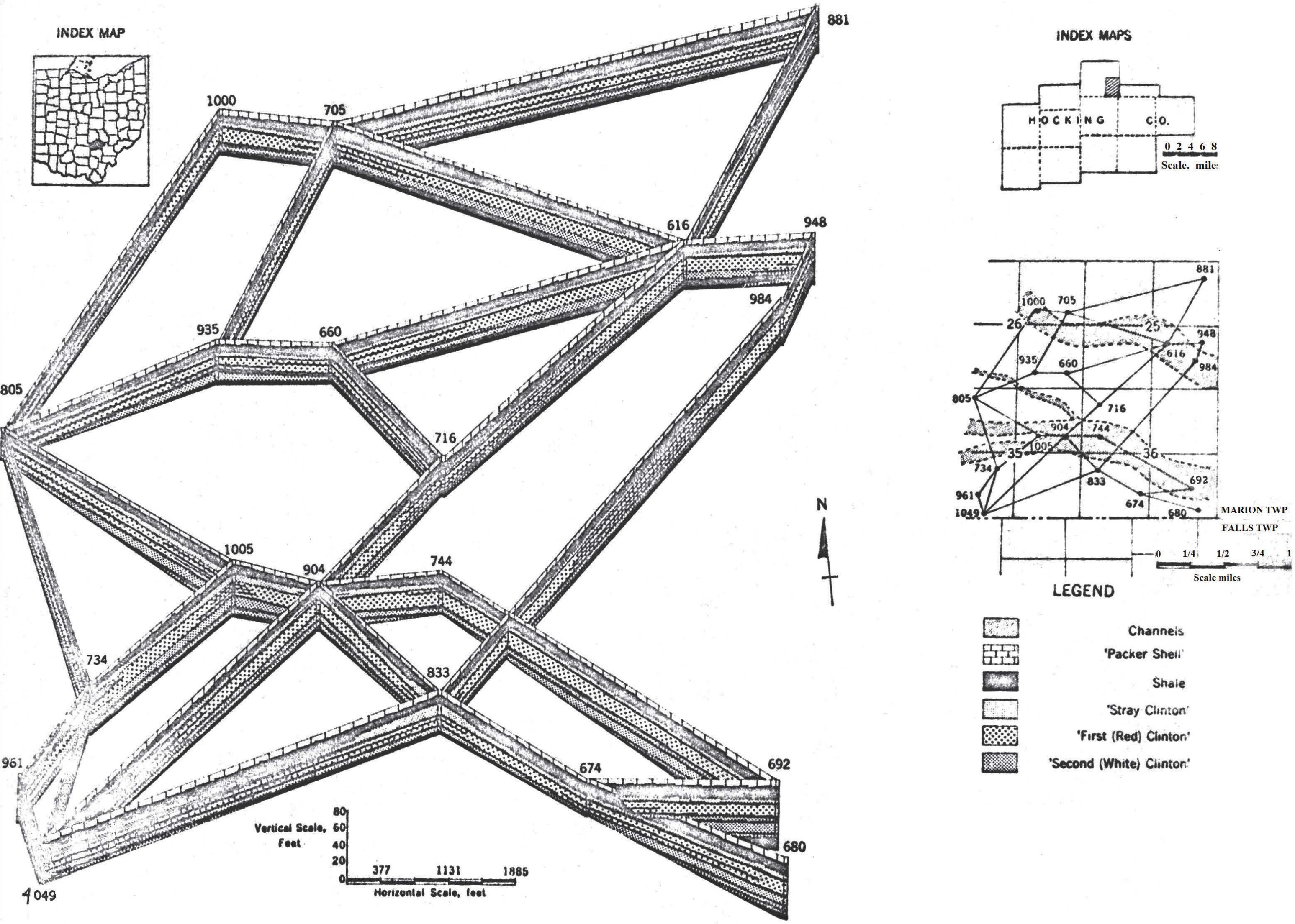


Figure 7. Panel diagram of the "Clinton Sandstone", Marion TWP. Hocking CO. Ohio (Overbey and Henniger, 1971).

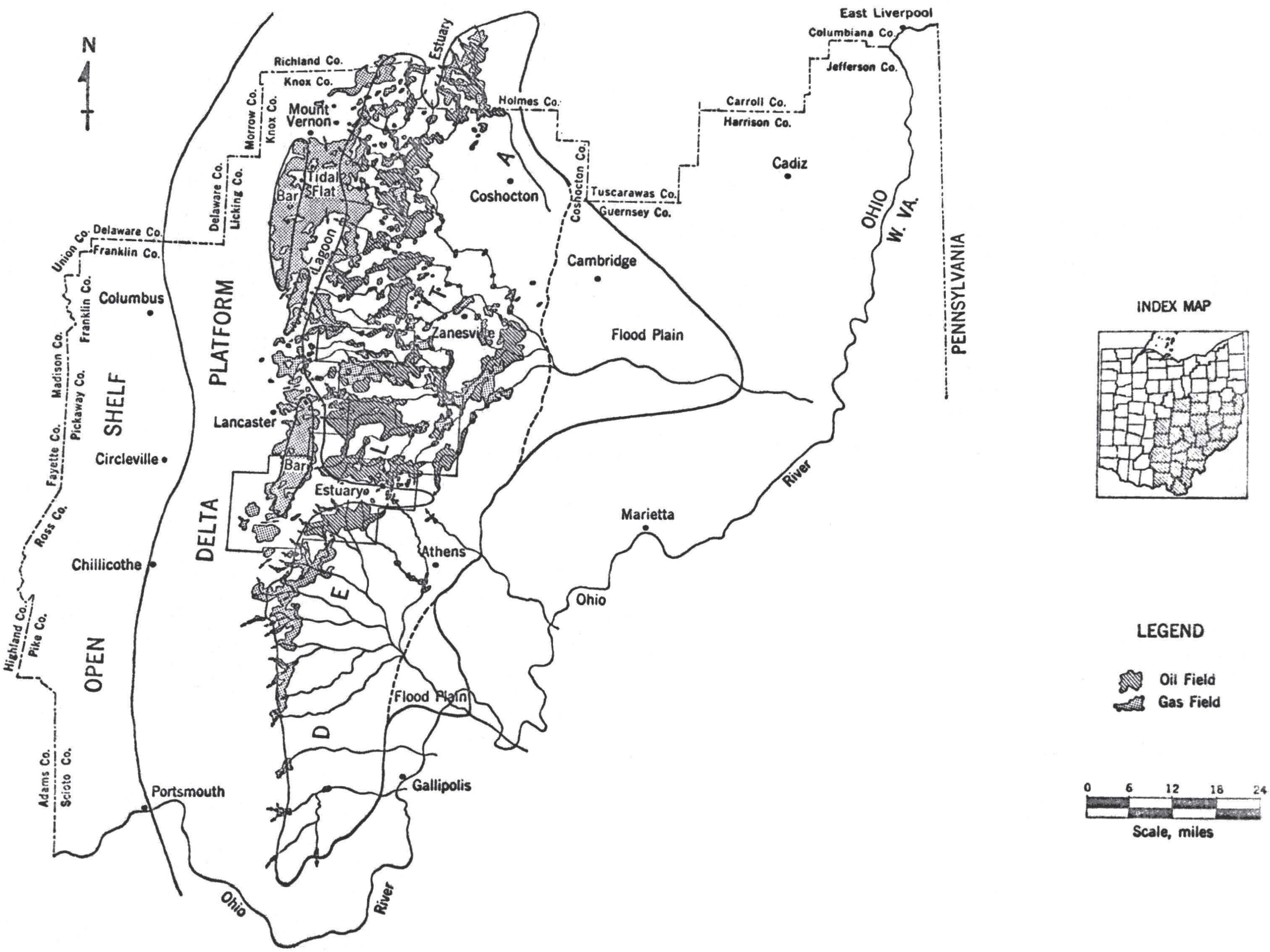
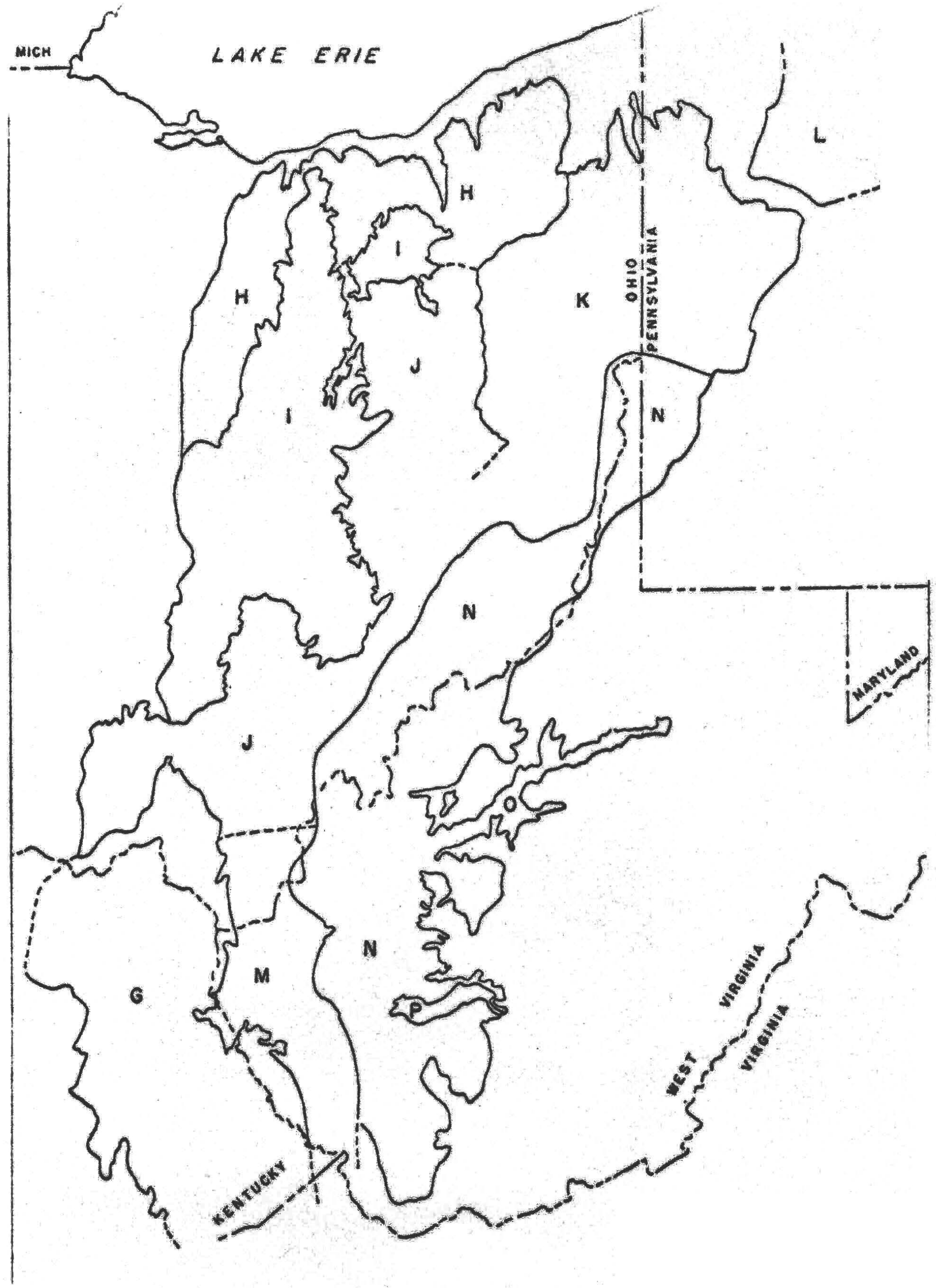


Figure 8. **Paleogeographic map of "Clinton" delta southeastern Ohio (Overbey and Henniger, 1971).**



G Area of silts of Bedford and Berea age
H Area of the Berea sandstone. A thick sheet of medium-to fine-grained sandstone underlain by medium-grained channel sandstones that contain small quartz pebbles at some places
I Area of thin marine sand which is equivalent to the upper part of the sheet sand of area H
J Area of a thick accumulation of fine-grained sand and silt
K Area of marine sand that averages about 40 feet thick over much of its extent
L Corry sand, largely silt and fine-grained sand
M Area of a thin sheet of silt spread offshore from area N
N Shoreline and near-shore deposits of sand and silt from a source area in Virginia, contains quartz pebbles at some places
O Sand of Berea age deposited in the Gay-Fink channnel
P Sand of Berea age deposited in the Cabin Creek channel

Figure 9. **Map showing the different areas of silt and sand deposition in the Berea and related sandstones in early Mississippian time (Pepper, De Witt and Demarest, 1954).**

The controlling factors of accumulation of oil and gas are porosity and permeability trends, and not structure (Bownocker, 1903). Analysis of the Cabin Creek channel (area P, Figure 9) demonstrates this. Here the Berea is divided into two parts, cap above and "pay" below. The cap, which is clear white hard quartzite, with a porosity of 4 per cent by Milcher's method, averages 15 feet thick, and thins to the northwest and southeast. The "pay", with a fairly sharp transition, is pure quartz sand with scattered flaxseed bodies of dark shale. The texture ranges from fine-grained to pebbly, with little cement and an average porosity of 16 per cent. The thickest "pay" is 35 feet, pinching out to the northeast and southwest where the two units together are less than 15 feet thick (Wasson and Wasson, 1929). The cap-rock and pay-sand relation can best be explained as a relatively uniform downward cementation of a sand-filled channel (Pepper, DeWitt and Demarest, 1954) (Figure 10). Occasional wells of large production in the Gay-Fink channel sand (area O and Figure 9) have been explained by lenses of pebbles and loose coarse sand distributed erractically through the stream channel (Pepper, DeWitt and Demarest, 1954).

In Early Bedford time the Second Berea sand bar was deposited on the east side of the Ohio bay, along the east side of the Red Bedford Delta (Figure 11). There are over 1,300 wells, most of them producing gas, in this sand body.

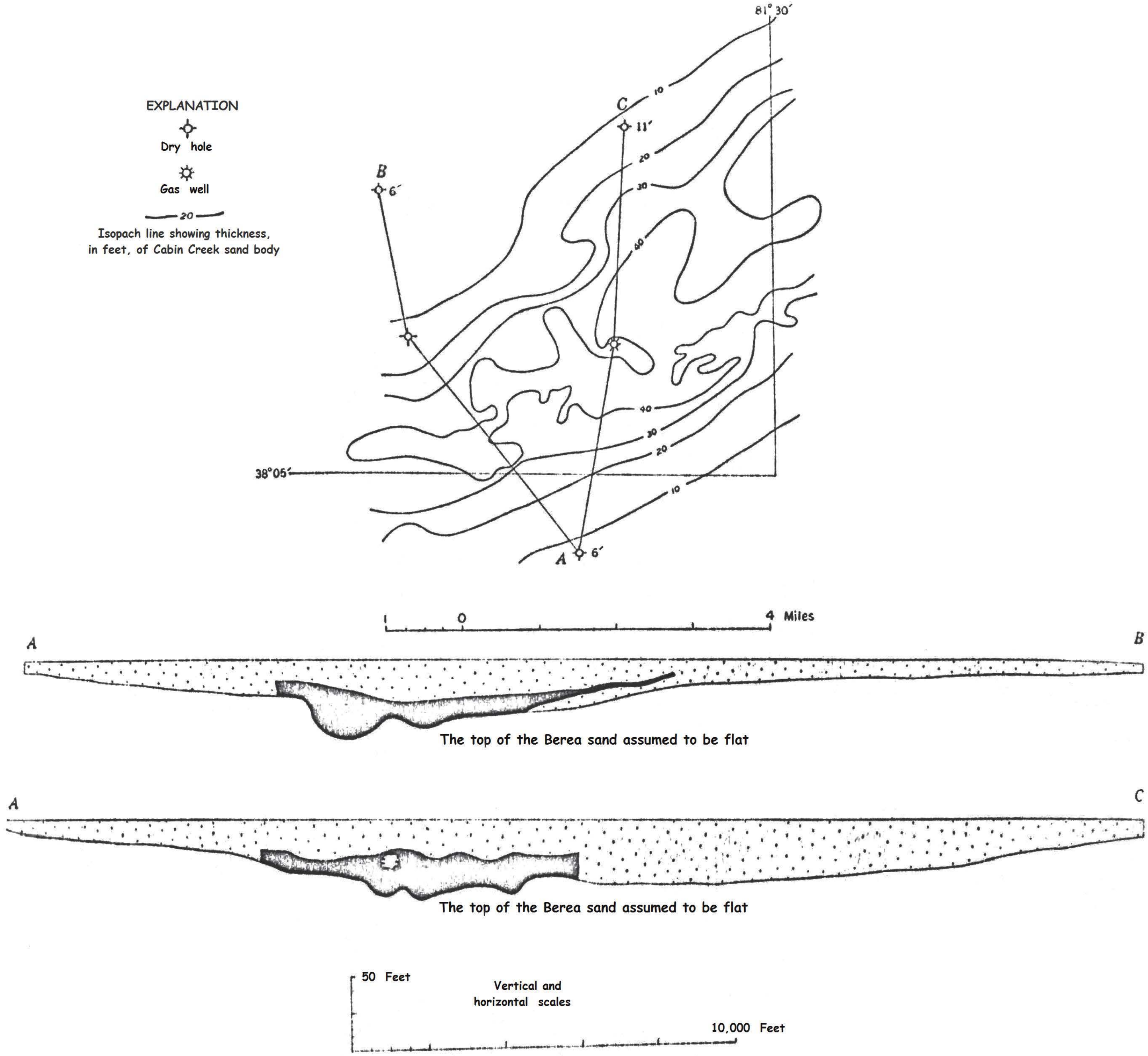


Figure 10. **Two sections across the sand body at Cabin Creek showing the position of the poorly cemented pay sand (black) and the more tightlty cemented parts of the sand body (dot pattern) (Pepper, De Witt and Demarest, 1954).**

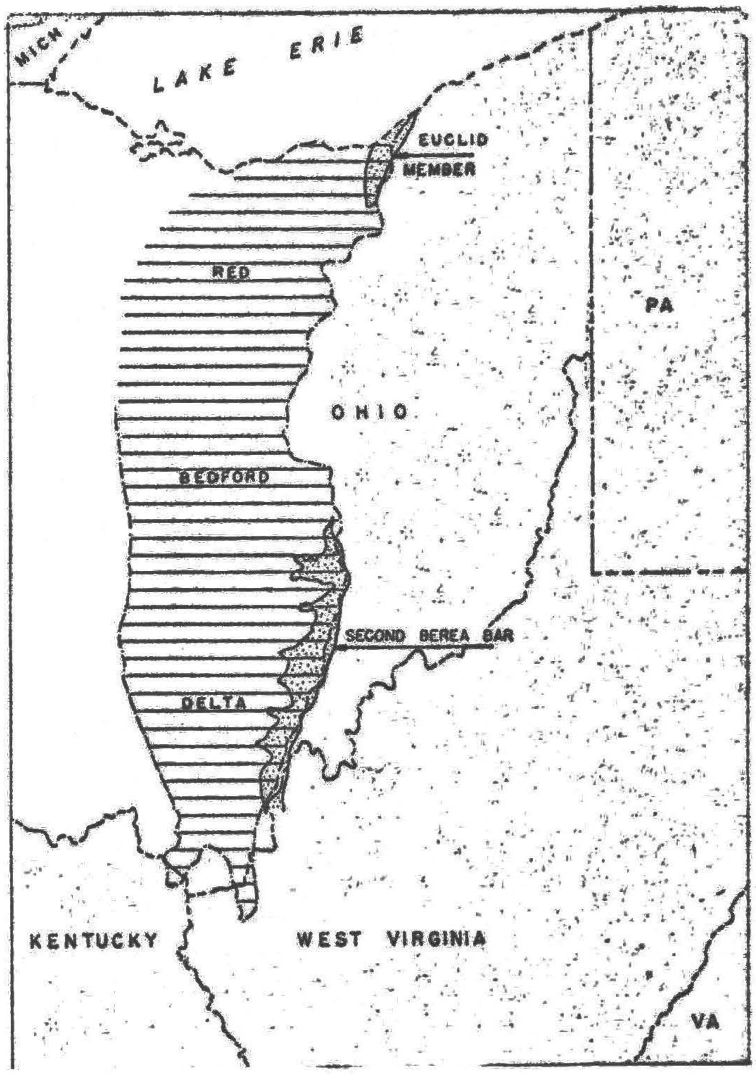


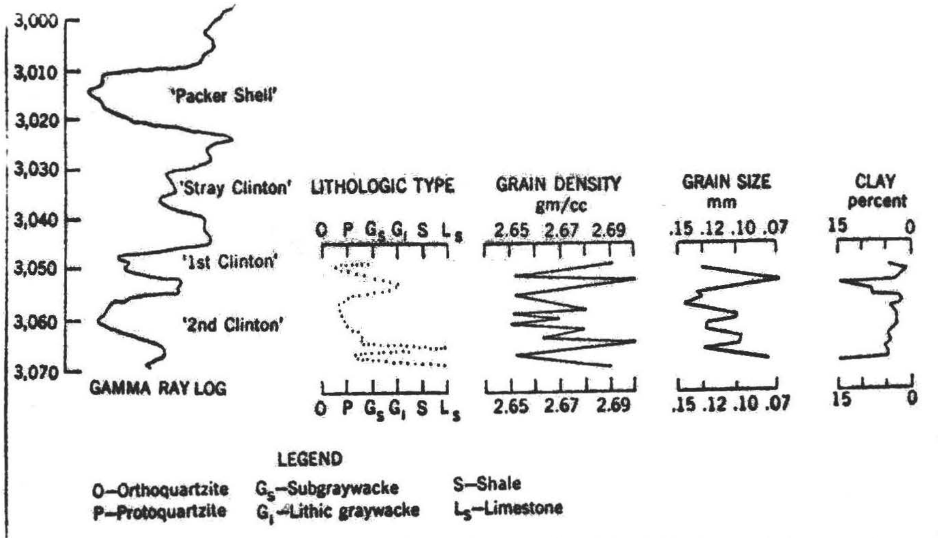
Figure 11. Sketch map showing the relation of the red muds of the Red Bedford Delta to the flanking barrier bars (Pepper, De Witt and Demarest, 1954).

In the "Clinton sands", oil and gas accumulate in stratigraphic traps, and structure is relatively unimportant. The reservoir-controlling parameters are interstitial clay content, shale stringers and laminations, degree of cementing, grain size, pore geometry, and thickness. Best production is from thick, shale-free distributary-channel deposits and delta-platform tidal channels (Overbey and Henniger, 1971).

In general, reservoir sand thickness ranges from 8 to 25 feet, averaging approximately 17 feet (Boley et al., 1965). Porous zones in the "Clinton" were formed furing original deposition. Later, some porous zones were changed in outline or modified by secondary deposition of silica, or by base exchange between the original minerals in the sand (Overbey and Henniger, 1971). Porous zones occur where current or wave action was greatest, forming belts of sorted sand such as beaches, bars or channel deposits (Pepper, DeWitt and Everhart, 1953). Initial production rates are higher from the thicker, more clay- and shale-free channels than from the interchannel areas (Overbey and Henniger, 1971). Comparison of the physical properties and their response on various types of well log is shown in Figure 12.

Future Production

Probably more pools in the Berea and "Clinton" will be discovered with improved mapping of the sand deposits and knowledge of their type of deposition. There is a possible extension of the "Clinton" gas field under the waters of Lake Erie (Landes, 1970).



COMPARISON OF LOG RESPONSE WITH PHYSICAL PROPERTIES

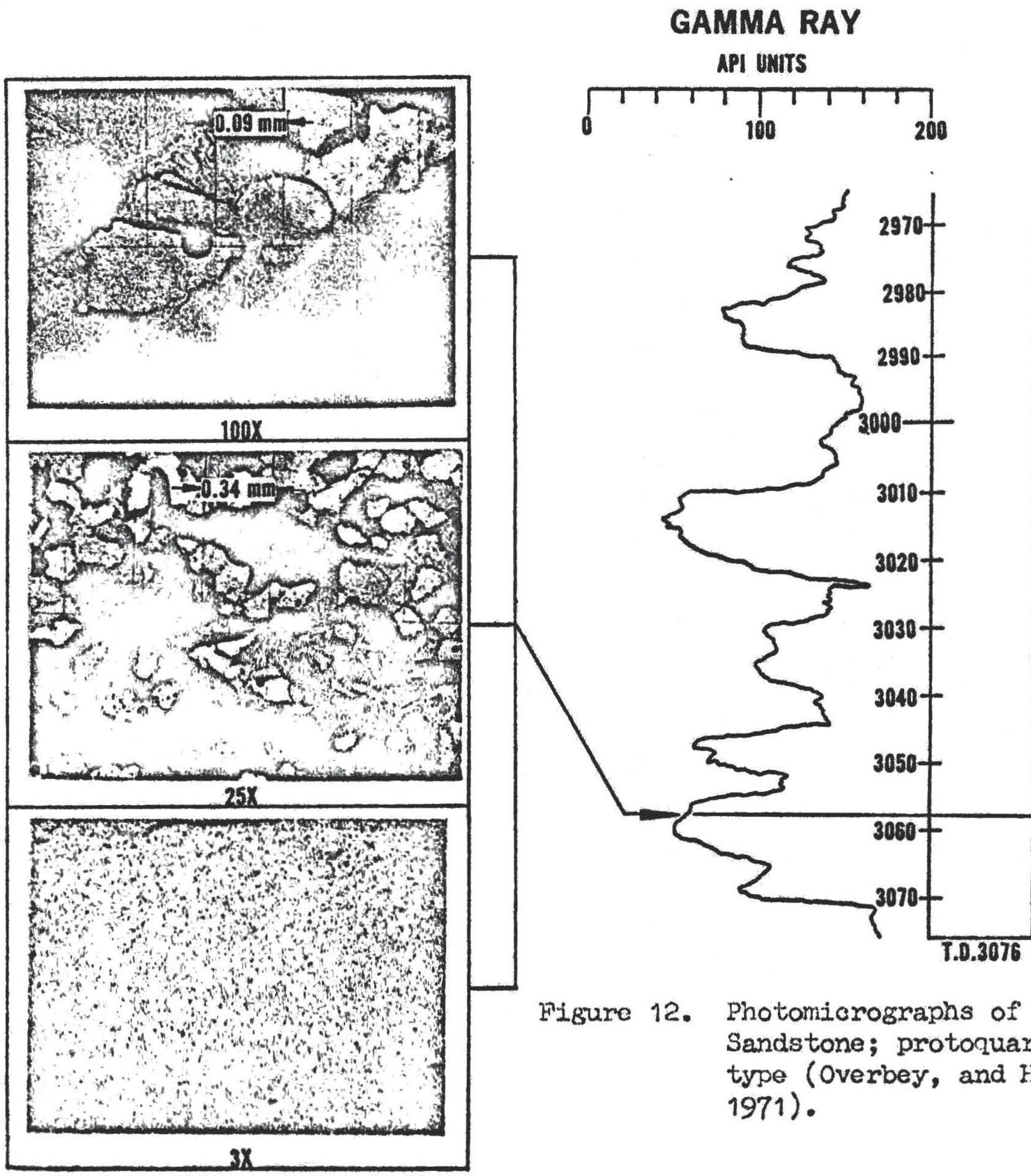


Figure 12. Photomicrographs of "Clinton" Sandstone; protoquartzite type (Overbey, and Henniger, 1971).

The lenticular nature, small size and low permeability of the Berea and "Clinton" sands do not promote successful waterflooding. However, some fields like the Logan oilfield contains a sufficient quantity of mobile oil and enough water-injection capacity to make waterflooding possible (Overbey and Henniger, 1971). The best secondary-recovery method appears to be gas repressuring. The success of both methods, though, depends on knowing the orientation of both natural and induced wellbore fractures so that injected fluids move in the reservoir in the direction of least resistance. Failure to know these relations may lead to a leak in the system.

Trenton Limestone

Accumulation

In northwestern Ohio the major producing unit is the Trenton Limestone. Current producing pools are shown on Plate 3. The Trenton, of Middle Ordovician age, lies between the Utica shale above and the Black River micritic limestone below.

Oil and gas accumulation in the Trenton is controlled by porosity due to dolomitization, and by structure. At least a 20 per cent magnesium-carbonate content is needed for production, and the best production is where the rock is a true dolomite (Carman and Stout, 1934). The Trenton is 420 feet thick but usually only the upper 20 to 30 feet is porous and dolomitic. However, some zones are 50 feet below the top and a few zones are found at levels of 100 to 300 feet. Production is chiefly from the upper 50 feet. East and south of the productive region, the magnesium-carbonate content rapidly decreases. To the west and north, into Indiana and Michigan, the dolomite continues (Carman and Stout, 1934). The porosity in the Lima-Indiana field is vuggy, not intercrystalline or intergranular (Rooney, 1966). The dolomite may be the thinning edge of a dolomite tongue from the northwest, or it may be the result of replacement of an original limestone (Carman and Stout, 1934). Several geologists have concluded that the porosity in the field resulted from solution by meteoric waters (Sanford, 1955; Shearrow, 1955; Girdley, 1961).

Most of the oil and gas production on the Findlay Arch (Figure 1) is related to a monocline and terrace structure, and to a fault, in Wood, Hancock, and Lucas counties (Carman and Stout, 1934). The monocline is formed by a narrow belt of steeper dip on the regional dip of the northern limb. Just above it on the limb there is a parallel belt of very gentle dip which forms a structural terrace. At some places, as in Lucas County, the monocline terrace structure is well down the limb, but elsewhere, as at Findlay and North Baltimore, the monocline is relatively near the axis of the Findlay Arch and the terrace becomes the marginal part of the broad undulating crest. Southwest of Wood County in Ohio and Indiana, the chief producing territory is on the upper part of the monocline on the north limb of the Findlay Arch. There the dip was steep enough for the oil to migrate up the monocline and accumulate at the lower edges of the terrace (Carman and Stout, 1934). The chief production in the Lima region is in an area 10 miles long and 3 miles wide where the Trenton is almost horizontal. Here the oil accumulated beneath a terrace just above a monocline to the north, and was prevented from rising further to the south by lack of porosity (Carman and Stout, 1934).

In Wood, Hancock, and Lucas counties the Findlay Arch is crossed by a fault trending N 10° W, which the drillers refer to as "the break". North of the Maumee River in Lucas County the displacement is about 200 feet for a distance of 6 to 8 miles. Westward it passes into the westward-dipping monocline discussed earlier, with the same direction across Lucas County and into Michigan (Carman and Stout, 1934). Along the falut zone the Trenton rocks and the overlying strata are broken and shattered, and wells are difficult and expensive to drill. However, these wells are usually better producers than those away from the break, because the shattered rock along the fault facilitates oil accumulation. The best production is on the downthrown or west side of the fault, where the producing zone rising to the east, is sealed against a nonporous limestone on the east side of the fault (Carman and Stout, 1934).

Oil production is restricted to the structures on the north limb of the arch. However, some gas was able to migrate under the less favorable conditions of dip and porosity to the broad undulating crest. These gas supplies were soon exhausted.

The Trenton reservoirs also contain salt water. In early years of production, the oil-water contact in the northern part of Ohio was about 500 feet below sea-level, in the Lima region about -400 feet, and at the state line about -300 feet. As the fields are exhausted of oil and gas, the salt water level rises (Carman and Stout, 1934). The probable source of the oil is the dolomite itself, or the overlying Utica shale, from which oil and gas accumulated where porosity and suitable structure existed above the salt-water level.

Future Production

There is the possibility of undiscovered deeper accumulations in the Trenton. This is possible because much of the porosity of the reservoirs is due to fracturing and because the Trenton itself might frequently be the source of the oil and gas. This allows for accumulation in any portion of the formation and at any horizon where there is sufficient porosity (Sanford, 1955).

Secondary recovery has not been used extensively and may yield some future production.

Copper Ridge Dolomite

Accumulation

In north-central Ohio, the major oil production is from the Copper Ridge Dolomite. Current producing pools are shown on Plate 4. The Knox unconformity separates the Copper Ridge Dolomite, Cambrian in age, from the overlying Chazy shale and limestone, of Middle Ordovician age (Figure 13). The Chepultepec and Lambs Chapel dolomites, which overlie the Knox

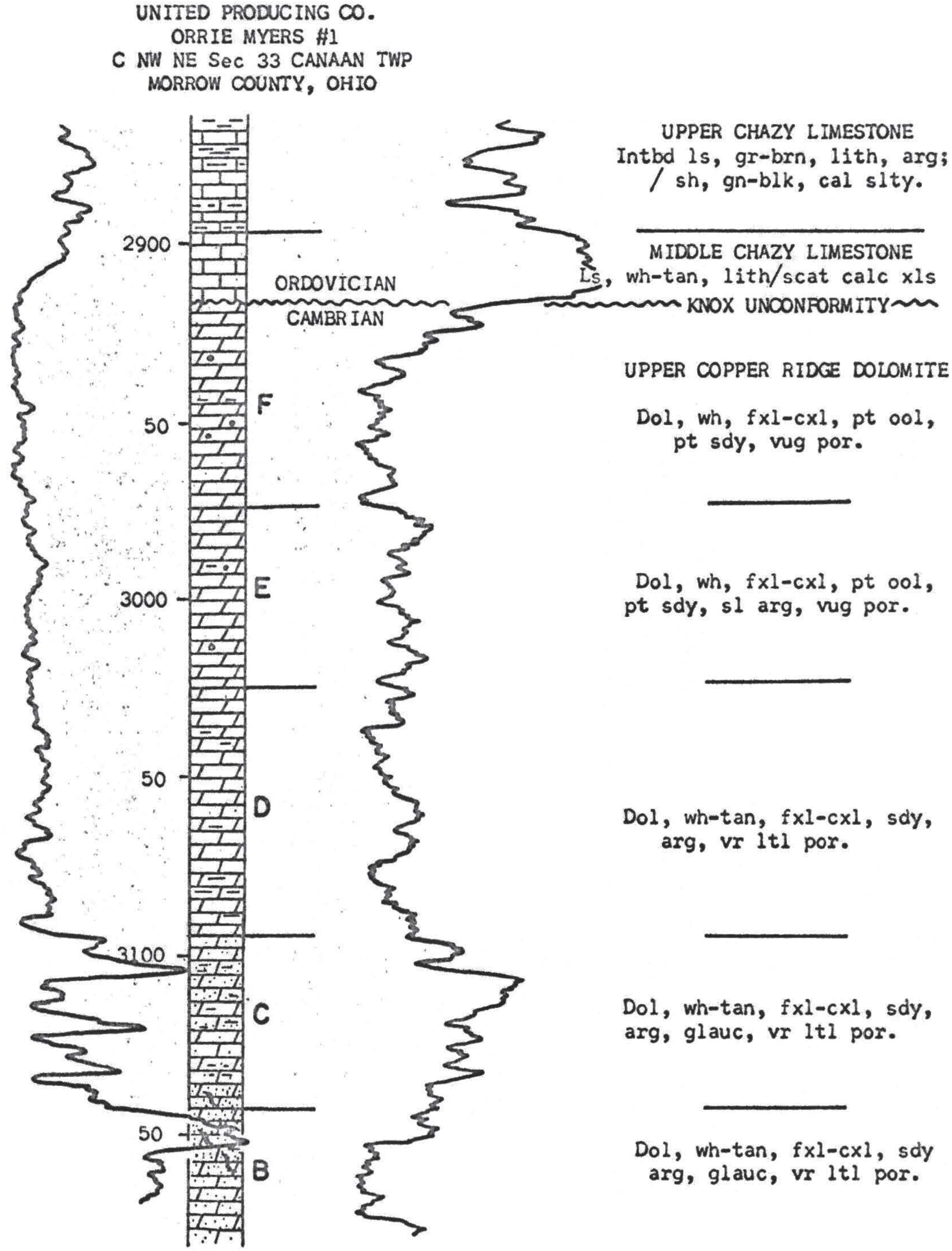


Figure 13. **Type log of Upper Cambrian-Lower and Middle Ordovician, showing sample descriptions and alphabetized zones B-F of upper Copper Ridge Dolomite (Dolly and Busch, 1972).**

unconformity to the east and west, are missing here due to erosion on the structurally high Waverly Arch.

Oil accumulation is in the porous and permeable erosional remnants of zones E and F of the Copper Ridge Dolomite. There has been no production below a depth of 150 feet below the erosional surface (Dolly and Blusch, 1972). There is no production from zones A through C, owing to a lack of porosity, probably because they were not exposed to subaerial processes. Zone D, although more porous than zones A through C and exposed to some weathering processes, is still not as porous as Zones E and F because of differences in lithology. Zone D is more massive and contains more argillaceious material. There has been some small production in locally fractured and dolomitized zones in the overlying Lowville and Chazy limestones (Figure 14). These oil accumulations may have been derived from the Lower Chazy shale or may have leaked from the Copper Ridge reservoirs.

Some geologists have indicated that the Knox Dolomite is of primary origin, with the source of magnesium-rich water from the north (Cooper, 1956; Dunbar and Rodgers, 1947). But others have concluded that the saccharoidal dolomites are replacement dolomites (Hohlt, 1948; Fairbridge, 1947: Parker, 1956; Edie, 1948; Waldschmidt et al., 1956; and Murray, 1960). Dolly and Busch (1972) showed, on examination of core slabs and thin sections, that the Copper Ridge is of replacement origin. The parent rock was primarily a fossiliferous calcarenite with a

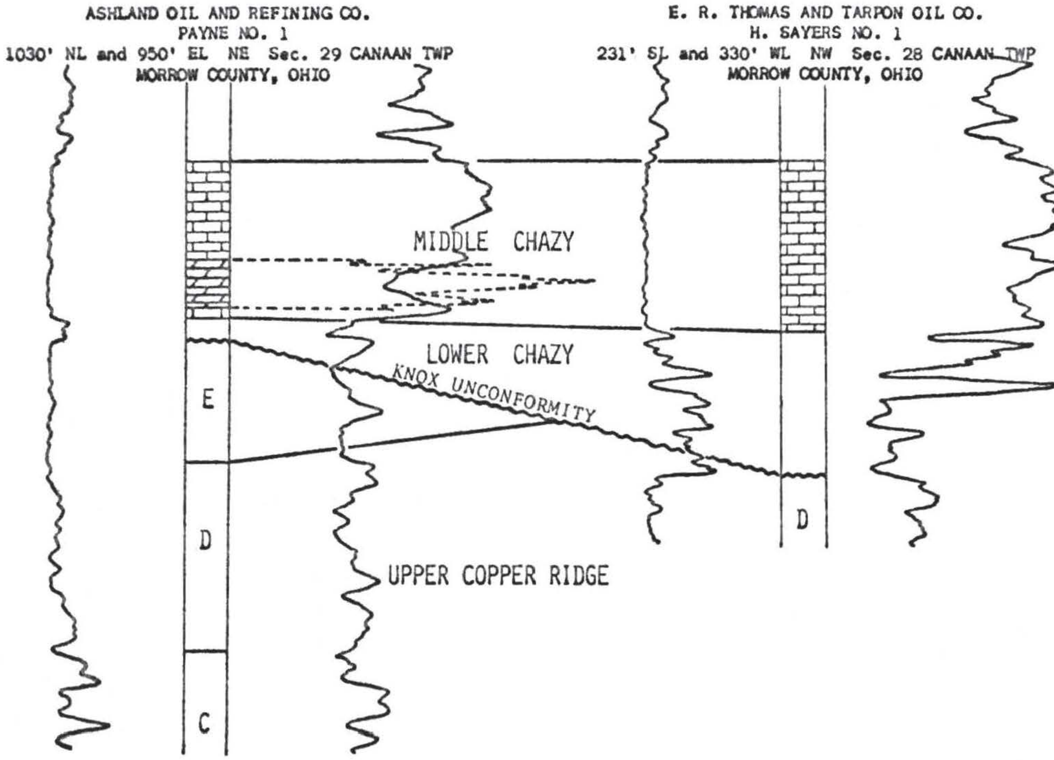


Figure 14. **Dolomite sone within middle Chazy Limestone (Dolly and Busch, 1972).**

few fine-grained carbonate mudstone layers scattered throughout the section. It is not known whether dolomitization occurred penecontemporaneously or as replacement after diagenesis and lithification. In either case it probably occurred before deposition of the overlying limestones.

Zones E and F compose the highest erosional remnants, which trend southeast and were formed by trellis drainage to the southeast. The hills are synclinal and the valleys anticlinal (Dolly and Busch, 1972))Figure 15). The lower Chazy shale, deposited in the valleys, was the source rock of the oil, and also acted as a cap rock. The hydrocarbons generated in the shale moved laterally along bedding planes until they intersected the unconformity. The regional tilt of the Knox unconformity is eastward. The hydrocarbons from the shales migrated along the unconformity westward until they encountered reservoir rock, Zones E and F, with intercrystalline, vuggy, and fracture porosity which were not affected by secondary cementation (Dolly and Busch, 1972). The hydrocarbons filled the erosional remnants to the top, displacing interstitial connate and meteoric water, and then moved along the unconformity to the next erosional remnant. The oil did not have sufficient buoyancy pressure to overcome the capillary pressure of the water occupying the pores of the overlying caprock (Dolly and Busch, 1972) (Figure 16).

The westward limit of oil production, at approximately the Marion-Morrow county boundary, was controlled mainly by two

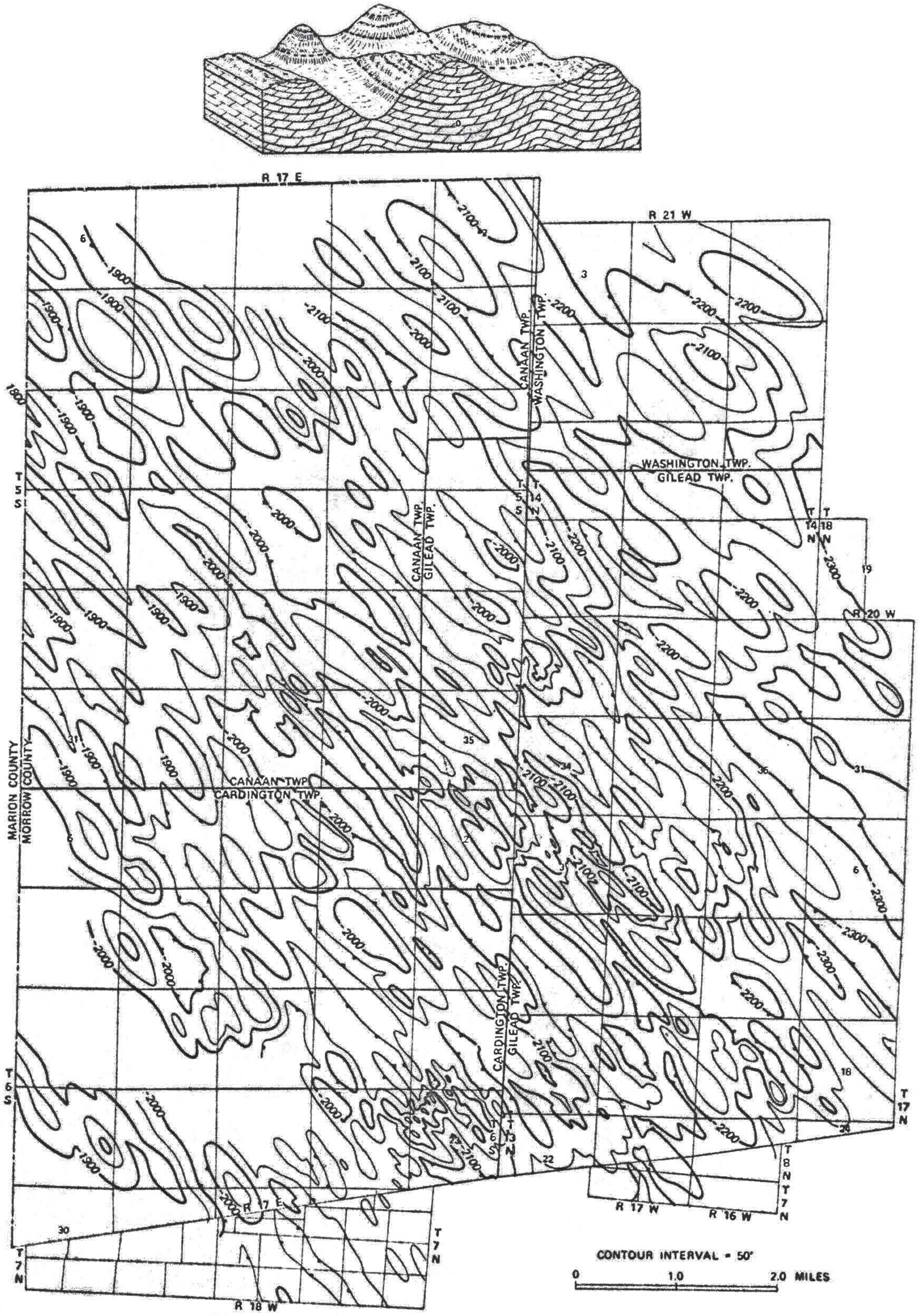


Figure 15. **Top, schematic block diagram showing topography of Knox erosion surface (Knox unconformity). Bottom, structural configuration of Knox unconformity in Morrow County, Ohio (Dolly and Busch, 1972).**

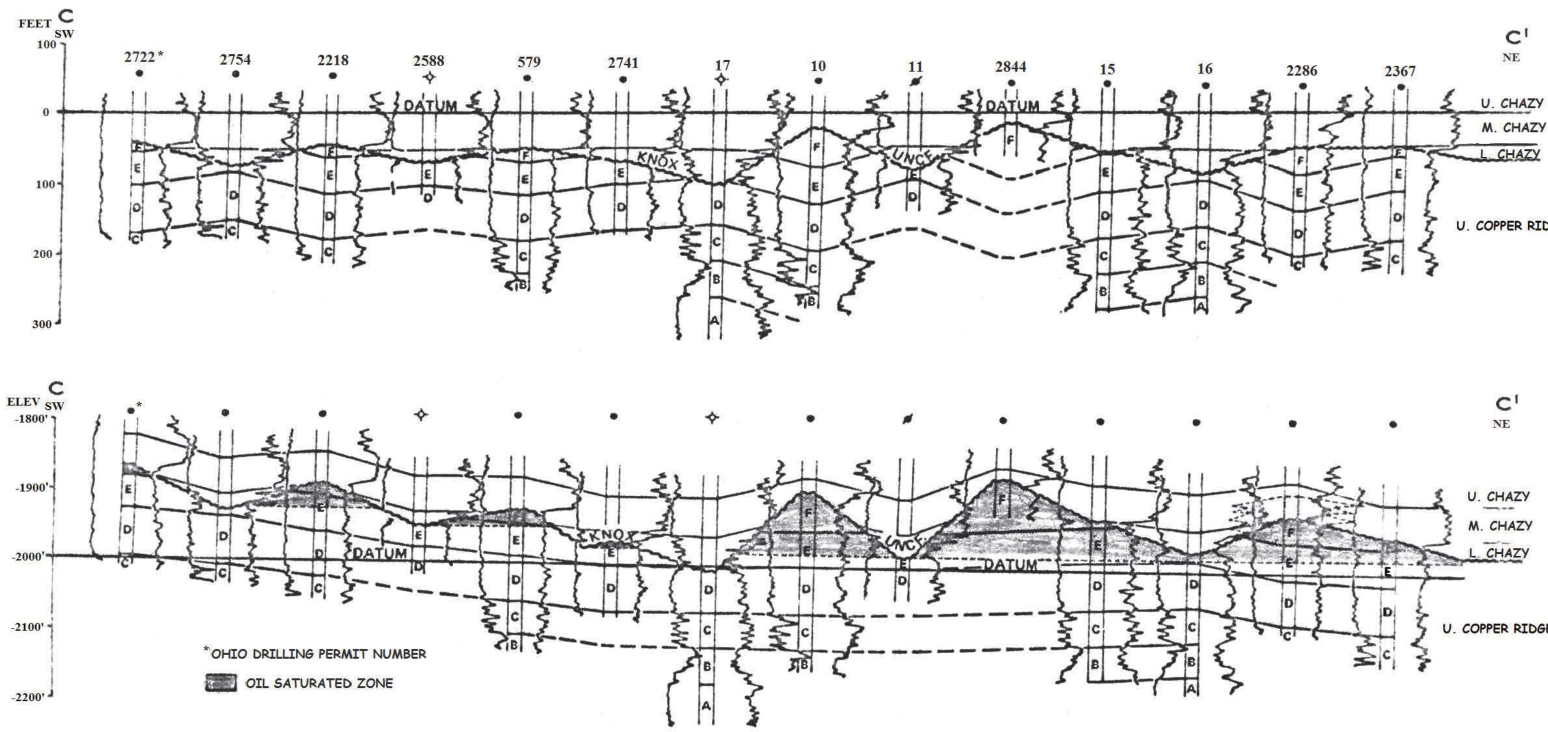
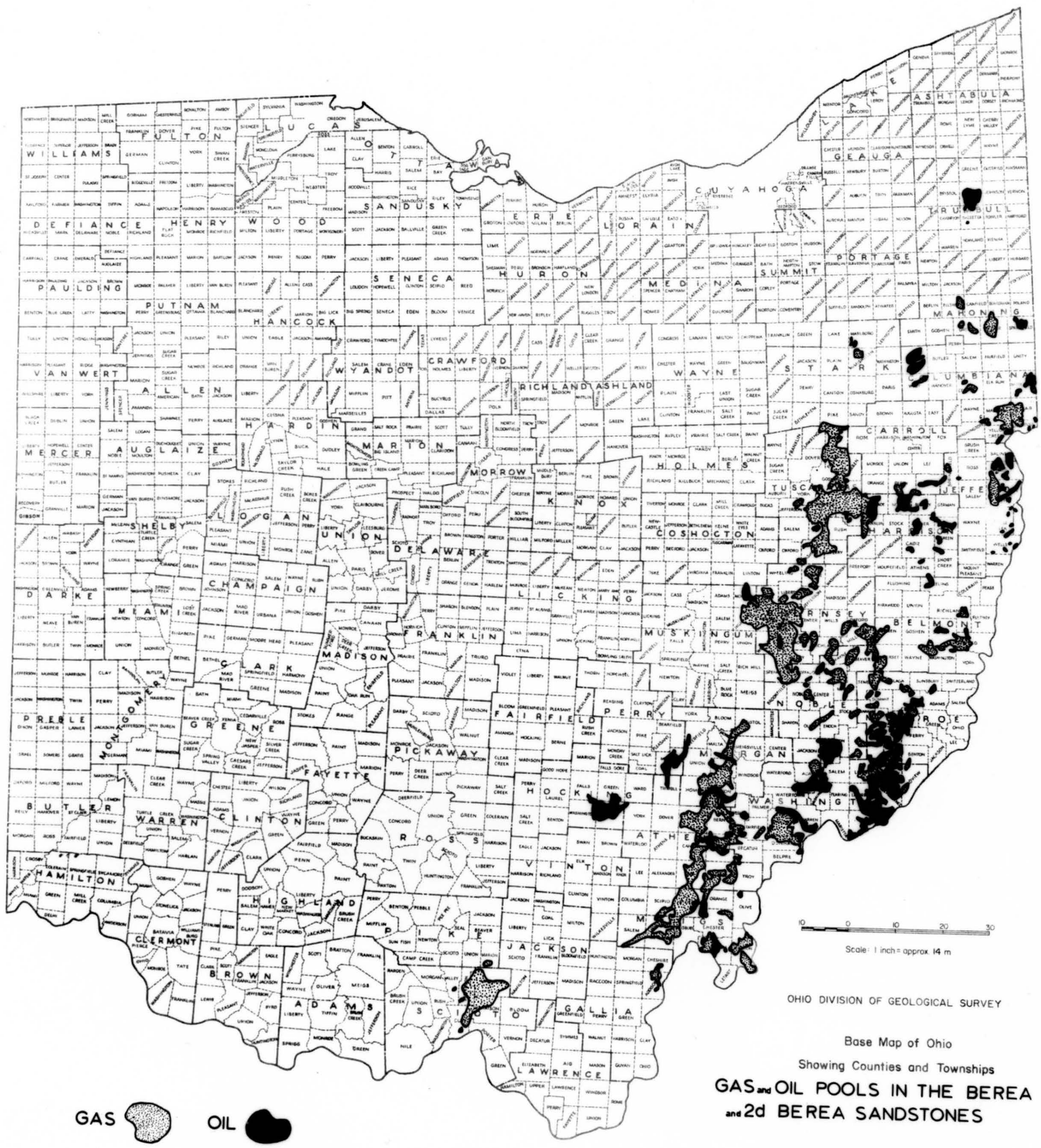


Figure 16. **Northeast-southwest cross-section in Morrow County showing oil accumulation (Dolly and Busch, 1972).**

factors. One, the supply of oil from the source rock decreases westward, as the lower Chazy becomes less shaly to the west and grades into the St. Peter Sandstone. Two, most of the Copper Ridge hills in Marion County are composed of the non-reservoir Zone D type of lithology. The scattered and erratic extent of Zones E and F do not provide a continuous pathway for long-distance migration (Dolly and Busch, 1972).

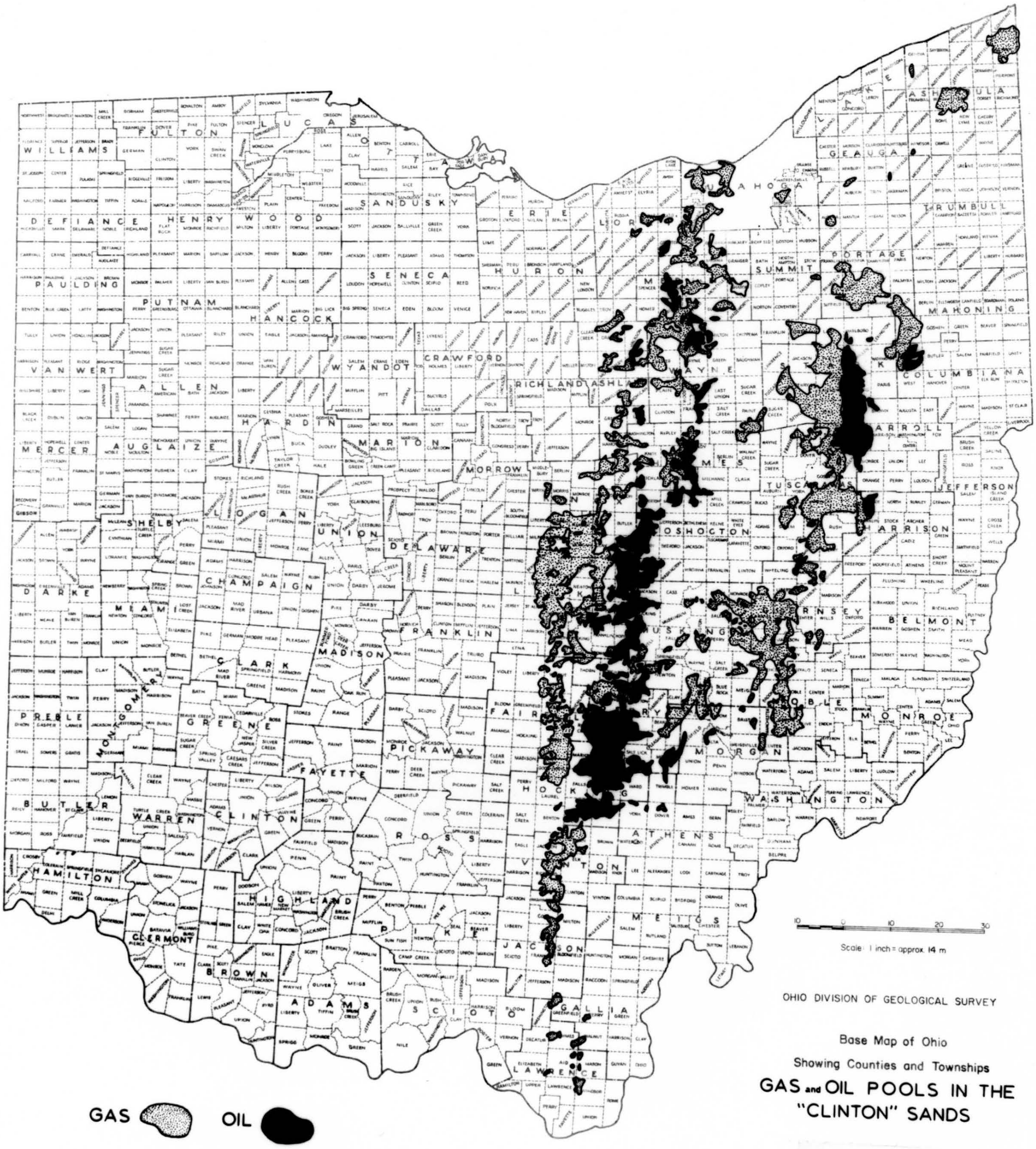
Future Production

Further production from the Knox Dolomite depends on more extensive mapping of the erosional remnants on the Knox unconformity. Waterflooding and gas repressuring would probably not be profitable, because pools are small and leakage might occur along the unconformity.



Scale: 1 inch = approx. 14 m
OHIO DIVISION OF GEOLOGICAL SURVEY
Base Map of Ohio
Showing Counties and Townships
GAS and OIL POOLS IN THE BEREA and 2d BEREA SANDSTONES
GAS
OIL

PLATE 1.



OHIO DIVISION OF GEOLOGICAL SURVEY

Base Map of Ohio

Showing Counties and Townships

GAS and OIL POOLS IN THE "CLINTON" SANDS

PLATE 2.

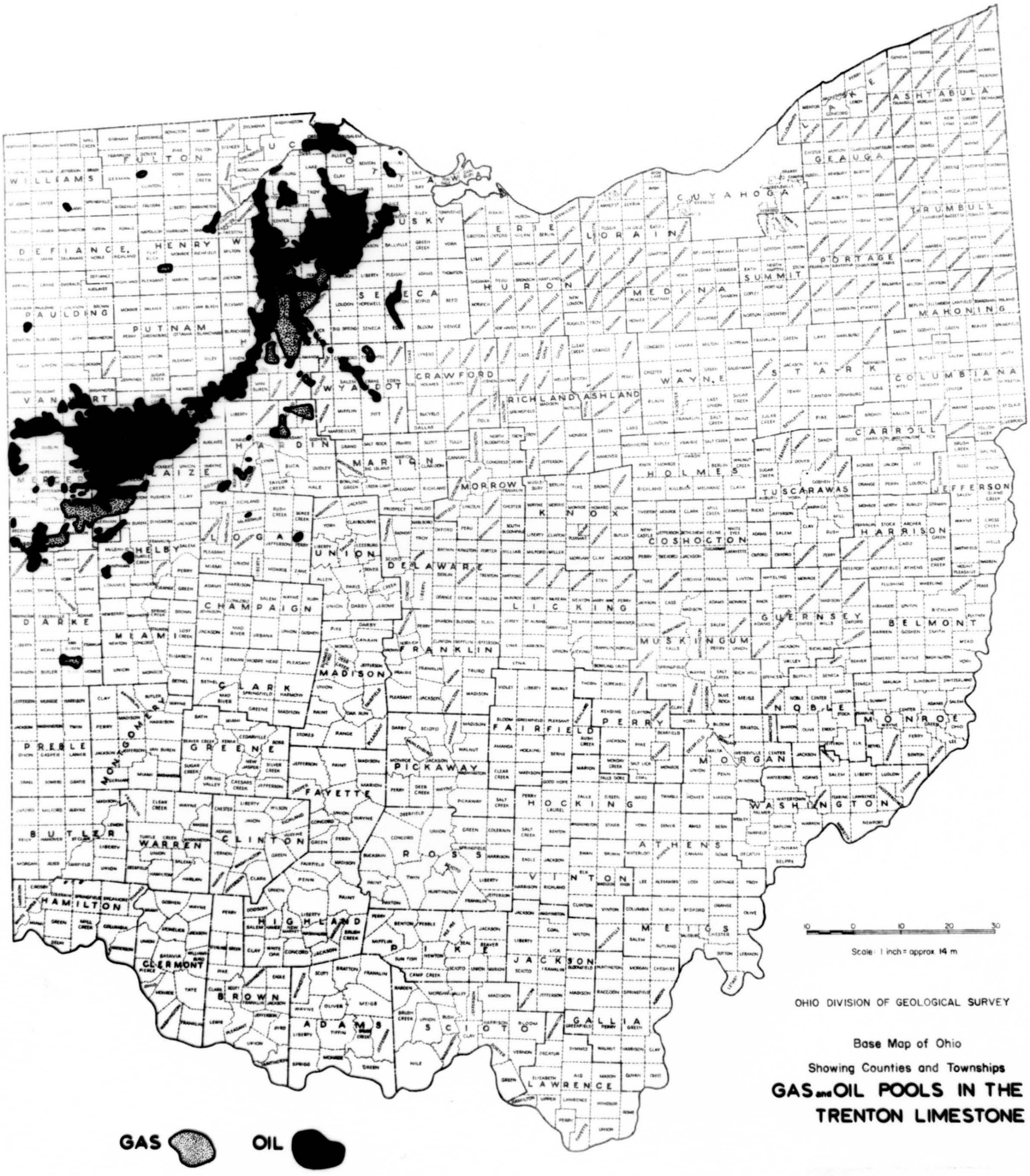

OHIO DIVISION OF GEOLOGICAL SURVEY
Base Map of Ohio
Showing Counties and Townships
GAS and OIL POOLS IN THE TRENTON LIMESTONE
Scale: 1 inch = approx. 14 m
GAS
OIL

PLATE 3.

OIL POOLS IN THE
COPPER RIDGE DOLOMITE

PLATE 4.

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